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NUMBER OF PLOTS REQUIRED FOR MEASURING
PRODUCTIVITY ON MOUNTAIN GRASSLANDS IN MONTANA

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ABSTRACT

The relationship between the number of 4.8-ft² plots used and precision in sampling production is shown for 12 grassland and shrubland habitat types. Total production and production of the graminoid class (grasses and sedges) can be determined with 80 percent probability of coming within ± 20 percent of the population mean by using no more than 10 plots on most of the habitat types. The forb and shrub classes, as well as individual species, are usually more variable and require substantially more plots for this level of precision. The need for range examiners to consider sampling accuracy when interpreting production data is stressed.

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KEYWORDS: sample size, grassland sampling, mountain grasslands, plot sampling, production estimates

The grazing capacity and degree of utilization on various range types within a grazing allotment are often determined by estimating or actually clipping vegetation from plots. Unfortunately, many range examiners tend to overlook the relationship between natural variability in vegetation and sampling requirements for reasonably precise estimates of productivity. The general instructions in Forest Service range analysis handbooks regarding plot numbers seldom indicate anticipated precision levels obtainable with the number of plots recommended. Unless the examiner statistically analyzes the variability of his data, he is unable to judge the accuracy of his production determinations. Consequently, he will lack perspective in using these data for evaluating grazing capacity.

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The purpose of this Research Note is to show the relationship between number of sample plots and precision of estimated production on 12 mountain grassland and shrubland habitat types² common to western Montana. This information should help the range manager obtain a more realistic view of the validity of his production estimates on these and similar habitat types.

Information presented in table 1 was developed from data obtained during a study to determine forage productivity and variability on important habitat types. Ten of the 12 habitat types are represented by three stands selected to span the range in productivity potential for the respective habitat type; the remaining two habitat types are represented by only two stands in each. A sampling technique combining estimation (40 plots) and clipping (10 plots) was used to determine production. The 10 clipped 4.8-ft² circular plots were randomly distributed within each stand. These clipped plots provided an estimate of the coefficient of variation (CV) by vegetation classes and species in each stand. The CV in turn forms the basis for determining the number of plots required to achieve given levels of sampling precision.

The formula used to compute the number of plots (N) needed for the specified levels of sampling precision (Freese 1967) shown in table 1 is:

$$N = \frac{(CV)^2 (t)^2}{(E)^2}$$

where CV = coefficient of variation, percent.
 E = desired error, percent of mean.
 t = "t" table value at desired probability level
 for estimated number of plots.

The coefficient of variation is a measure of plot-to-plot variability (standard deviation), here expressed as a percent of the mean. Variability in production between plots is determined primarily by the relationship between plot size and the distribution of the plants. For example, this variation is less on a bluegrass pasture than on a scattered bunchgrass range when each is sampled by the same size plots. Although sampling variability can usually be decreased by increasing plot size, the time required to measure the vegetation also increases as the plots become larger. I have concluded from over a decade of experience on Montana rangelands that a 4.8-ft² circular plot is a suitable compromise for measuring herbaceous production on most mountain grassland types. This size agrees with the findings of Van Dyne and others (1963) during their study of the efficiency of plot size and shape for measuring production on a bunchgrass range in southwestern Montana. They found that 4-ft² plots were more efficient than either 2- or 6-ft² plots and that circular plots were more efficient than either square or rectangular plots.

The more sparsely and unevenly plants are distributed on an area, the more plots of a given size must be measured to estimate production with the same degree of precision. Overall production on a range type may appear fairly uniform; however, production of individual species and sometimes of vegetation classes is often very uneven. Usually, we must sacrifice some of the desired precision to "getting-the-job-done" in a limited period of time. For example, to achieve sampling precision within ±10 percent of the mean usually requires three to four times as many plots as ±20 percent. Similarly, to be 90 percent confident that the true mean will be within the desired range of the sample mean will often take at least half again as many plots as settling for a confidence level of 80 percent. The 80 percent confidence level appears to be a reasonable

²Mueggler, W. F., and W. P. Handl. 1974. Mountain grassland and shrubland habitat types in western Montana--an interim report. USDA Forest Service, Intermountain Forest and Range Experiment Station, and Northern Region, 89 p. Missoula, Montana.

Table 1.--Number of randomly distributed 4.8-ft² plots required to achieve sampling precision (E) of ± 10 , 20, and 30 percent of the mean production of each population in various habitat types (H.T.), at the 80 percent confidence level with the coefficient of variation (CV) percentages encountered

	VEGETATION CLASSES			MAJOR SPECIES		
	Total	Graminoids	Forbs			
<i>STIPA COMATA/BOUTELOUA GRACILIS</i> H.T.						
				<i>Bouteloua gracilis</i>	<i>Stipa comata</i>	
CV	25-38	16-19	49-211	24	64-122	
E ± 10	12-25	6-7	40-730	12	71-244	
E ± 20	4-7	2-3	11-183	4	19-63	
E ± 30	3-4	2	6-83	2	9-28	
<i>AGROPYRON SPICATUM/BOUTELOUA GRACILIS</i> H.T.						
				<i>Agropyron spicatum</i>	<i>Artemisia frigida</i>	
CV	10-21	20-42	30-36	38-58	58-67	
E ± 10	3-9	8-30	16-23	25-57	56-74	
E ± 20	2-3	3-8	5-7	7-15	15-20	
E ± 30	1-2	2-4	3-4	4-8	7-9	
<i>AGROPYRON SPICATUM/A. SMITHII - A. DASYSTACHYUM</i> H.T.						
				<i>Agropyron spicatum</i>		
CV	45-56	55-66	67-143	70-123		
E ± 10	34-53	50-74	76-335	81-250		
E ± 20	10-14	14-19	20-85	21-64		
E ± 30	5-7	7-9	10-39	10-29		
<i>FESTUCA IDAHOENSIS/A. SMITHII - A. DASYSTACHYUM</i> H.T.						
				<i>Festuca idahoensis</i>	<i>Agropyron smithii</i>	
CV	13-29	12-34	11-44	33-54	37-103	
E ± 10	4-15	4-21	3-34	19-50	24-175	
E ± 20	2-5	2-6	2-9	6-13	7-45	
E ± 30	2-3	1-4	1-5	3-7	4-21	
<i>FESTUCA IDAHOENSIS/AGROPYRON SPICATUM</i> H.T.						
				<i>Festuca idahoensis</i>	<i>Agropyron spicatum</i>	
CV	15-25	10-42	18-75	19-138	54-106	
E ± 10	5-12	2-31	6-93	8-315	49-186	
E ± 20	2-4	2-9	3-24	3-80	13-48	
E ± 30	2	1-5	2-12	2-36	7-22	
<i>FESTUCA IDAHOENSIS/AGROPYRON CANINUM</i> H.T.						
				<i>Festuca idahoensis</i>	<i>Bromus carinatus</i>	<i>Lupinus sericeus</i>
CV	18-24	23-37	20-38	39-70	106-117	71
E ± 10	9-11	10-24	8-25	27-83	185-226	85
E ± 20	3-4	4-7	3-7	8-21	47-58	22
E ± 30	2	2-4	2-4	4-10	22-26	11

(con.)

Table 1.--(con.)

VEGETATION CLASSES				MAJOR SPECIES		
	Total	Graminoids	Forbs			
<i>FESTUCA SCABRELLA</i> / <i>AGROPYRON SPICATUM</i> H.T.						
				<i>Festuca scabrella</i>	<i>Festuca idahoensis</i>	<i>Lupinus sericeus</i>
CV	20-34	27-43	52-71	41-58	48-73	90-178
E±10	8-21	14-32	46-84	29-57	40-88	276-518
E±20	3-6	4-9	12-22	8-15	11-23	70-130
E±30	2-3	3-5	6-11	4-8	6-11	32-59
<i>FESTUCA SCABRELLA</i> / <i>FESTUCA IDAHOENSIS</i> H.T.						
				<i>Festuca scabrella</i>	<i>Festuca idahoensis</i>	
CV	21-45	19-47	64-134	19-71	79-84	
E±10	9-34	7-38	68-221	7-84	104-116	
E±20	3-10	3-11	18-56	3-22	27-30	
E±30	2-5	2-5	9-26	2-11	13-14	
<i>ARTEMISIA TRIDENTATA</i> / <i>AGROPYRON SPICATUM</i> H.T.						
				<i>Artemisia tridentata</i>	<i>Agropyron spicatum</i>	
CV	32-57	33-60	67-125	107-179	50-70	
E±10	19-55	19-60	75-255	187-526	42-81	
E±20	6-15	6-16	20-65	48-131	12-21	
E±30	3-7	3-8	9-30	22-60	6-10	
<i>ARTEMISIA TRIDENTATA</i> / <i>FESTUCA IDAHOENSIS</i> H.T.						
				<i>Artemisia tridentata</i>	<i>Festuca idahoensis</i>	
CV	27-57	37-43	35-53	82-174	34-40	
E±10	13-55	24-31	22-47	113-496	20-28	
E±20	4-15	7-9	6-13	29-124	6-8	
E±30	3-7	4-5	4-6	14-56	3-4	
<i>POTENTILLA FRUTICOSA</i> / <i>FESTUCA SCABRELLA</i> H.T.						
				<i>Potentilla fruticosa</i>	<i>Festuca scabrella</i>	
CV	15-26	27-28	40-47	173-276	30-77	
E±10	5-13	13-14	28-38	492-1248	16-98	
E±20	2-4	4-5	8-10	124-312	4-25	
E±30	2	3	4-5	56-140	3-12	
<i>PURSHIA TRIDENTATA</i> / <i>FESTUCA SCABRELLA</i> H.T.						
				<i>Purshia tridentata</i>	<i>Festuca scabrella</i>	
CV	52-60	41-45	78-86	154-316	123-174	
E±10	45-60	28-35	100-124	375-1642	250-500	
E±20	12-16	8-10	26-32	95-411	64-125	
E±30	6-8	4-5	12-15	43-182	29-57	

compromise for much of our range production sampling. Therefore, it is used in table 1 as the probability level for sampling precision levels of ± 10 , ± 20 , and ± 30 percent of the estimated population mean.

RESULTS AND DISCUSSION

Neither vegetation production nor its distribution over the land surface are uniform between stands within a habitat type classification unit. The differences in areal distribution are reflected by the range in CV values, which in turn dictates sample plot requirements for desired levels of precision (table 1).

Fortunately, on these habitat types, production of the graminoid vegetation class (total grasses and sedges) can be sampled to the same level of precision as total vegetation with a similar number of plots. Forb production, however, usually is more varied and sampling precision will be considerably lower unless more plots are measured. Production of only the most abundant individual species can be sampled to reasonably precise levels within the plot/time constraints usually faced by range examiners. The major grass species are more easily sampled than either the forb or shrub species. An accurate measure of shrub production can involve a seemingly impossible number of 4.8-ft² plots. When this situation occurs, some other approach to shrub production should be considered, such as using larger plots designed specifically for the shrubs or reducing accuracy requirements.

The information contained in table 1 merely serves as a guide to sampling requirements for determining forage production. One can easily calculate requirements for a specific area by computing the CV either from data collected in previous years or from a limited number of sample plots. Once the CV is obtained, plot requirements to achieve desired levels of precision can easily be computed by the formula already given.

A range examiner often will not have the time to clip the sometimes large number of plots required to reach desired precision levels. In such cases, either the desired level must be reduced or alternatives to clipping used, such as weight estimates, ranking, or double sampling (Reppert and others 1963). Given the same number of plots, however, all methods of visual estimation introduce greater potential error in determining production on a plot than does actual clipping.

An estimation approach that I have found useful for expanding plot numbers is to rate production on four plots with reference to production on a central clipped plot. The four rated and one clipped plot constitute a set. The number of randomly distributed sets used is determined by the level of precision desired. The five plots within a set are located within easy view of one another so that production on each rated plot can easily be estimated as a percent of that on the plot to be clipped. Total production, production by vegetation classes, and by major species, if desired, are estimated as a percent of that produced on the plot that will be clipped. Following clipping and weighing by the selected categories, the percentage figures for each rated plot are converted to weight. Thus, production values for five plots can be obtained by clipping only one. Of course, measurement error will be greater on the rated than on the clipped plots. But, this disadvantage is also true for estimating weight by weight units. Rating in percent, however, circumvents the disadvantage of establishing and mentally maintaining the weight units required for weight estimates.

Regardless of the method used to obtain herbage production, the range examiner should be aware of the probable accuracy of his data. Preferably, he should compute the statistical confidence limits of his data, bearing in mind the possible error involved in plot measurements. Then he would be in a position to tailor his conclusions regarding production to the precision level of his data.

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